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Sustainable nations: what do aggregate indexes tell us?

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Abstract What is a 'sustainable nation' and how can we identify and rank 'sustainable nations?' Are nations producing and consuming in a sustainable way? Although several aggregate indexes have been proposed to answer such questions, comprehensive and internationally comparable data are not available for most of these. This paper quantitatively compares three aggregate indexes of sustainability: the World Bank's 'Genuine Savings' measure, the 'Ecological Footprint,' and the 'Environmental Sustainability Index.' These three indexes are available for a large number of countries and also seem to be the most influential among the aggregate indexes. This paper first discusses the main limitations and weaknesses of each of these indexes. Subsequently, it shows that rankings of sustainable nations and aggregate assessments of unsustainable world population and

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world GDP shares vary considerably among these indexes. This disagreement leads to suggestions for analysis and policy. One important insight is that climate change, arguable the most serious threat currently faced by humanity, is not or arbitrarily captured by the indexes.

Keywords Adjusted net savings · Ecological debt · Ecological Footprint · Environmental Sustainability Index · Genuine Savings · Sustainability

1 Introduction

Environmentally sustainable development is a core national and global issue. According to the Brundtland Commission it is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment Development 1987). It is still an open question what criteria should be used to decide whether a nation is on a sustainable path. National accounting measures such as GDP fail to address several critical dimensions, including environmental sustainability of production and consumption (e.g., van den Bergh 2007). Research progress in environment and development economics has generated a variety of aggregate indexes to evaluate and monitor sustainable development and its counterpart, namely overshoot of natural resource use and unsustainable environmental pressure. A critical question is whether these indexes are able to sufficiently capture the multidimensional nature of sustainable development and identify and rank nations accordingly. A related and important question is whether any of these indexes can deliver reliable information to assess whether all nations together are consuming the ecosystem resources at a sustainable level. The purpose of this paper is to critically examine what aggregate measures say about nations and the world economy as a whole in terms of sustainability.

The paper is organized as follows. Section 2 briefly discusses the various indexes reflecting sustainability. Section 3 compares the empirical performance of three important indictors in identifying and ranking 'sustainable nations' and in assessing the sustainability of the world economy and population. Section 4 offers policy implications and concluding remarks.

2 Aggregate sustainability indexes

Many indicators have attempted to capture the various dimensions of sustainability. They vary in terms of sub-components as well as the way these are combined or aggregated. Prominent among these aggregate indexes are: Genuine Savings (GS), the Ecological Footprint (EF), the Environmental Sustainability Index (ESI), the Genuine Progress Indicator (GPI), and the Index of Sustainable Economic Welfare (ISEW). Other well-known indexes are HANPP (human appropriation of net primary production) proposed by Vitousek et al. (1986) and the Wuppertal Institute concepts MIPS (material input per unit service), TMF (total material flow), and ecological rucksack, which sum direct and indirect material use (measured in kg) in production, including land removal in mining (Schmidt-Bleek 1993). All these indexes rely on some type of reduction of multidimensional effects to a single unit, be it money, energy, or land area. This has been criticized as assuming commensurability of values (Martinez-Alier et al. 1998) or as reflecting some specific value theory (e.g., land, energy or weight value theory) (van den Bergh and Verbruggen 1999). Another general criticism is that many of these indexes implicitly weight components without a convincing basis in natural or social sciences, that is, relative impact on ecosystem functioning or preferences of humans. For example, MIPS and TMF just add together kilograms of substances with entirely different environmental impacts (e.g., toxic materials and gravel).

The EF has received a number of specific criticisms (see Forum discussion in *Ecological Economics* vol. 32, pp. 341–389). It has been said to represent a case of "false concreteness" as it calculates land area used by a system as if it were sustainable, leading to transformation of an unsustainable to a sustainable situation. This requires assumptions, which make the result hypothetical instead of concrete land use. Another (repeated) criticism is that the 'sustainable energy scenario' ('carbon sink' land) component of the EF is arbitrary and infeasible, among others, as it will be economically and politically countered by extremely high pressure on land and food prices (as is currently occurring due to biofuel crops planting). The EF does not take other, currently feasible, strategies like large scale PV, solar heat, and wind into account.

While the EF is ultimately based in ecology (overshoot, natural capital), GS, ESI, GPI, ISEW combine environmental with selected macroeconomic and social indicators. Though seemingly conceptually useful (e.g., Lawn 2003; Neumayer 2000), GPI and ISEW calculations only cover a limited number of countries. To make things more complex, some versions of the GPI include EF components. The material indicators MIPS and TMF are too crude, narrow, and indirect to capture environmental effects broadly in an accurate way. Moreover, GS has received considerable interest given that was first developed and published by the World Bank, EF has been marketed extensively by World-wide Fund for Nature International (WWF) through Living Planet Reports, which have resulted in media headlines on ecological debt and overshoot. ESI has been supported by the World Economic Forum (WEF). ESI was made public in 2000 at the meeting of WEF in Davos and hailed by the global business community as an important environmental management and policy tool. Comprehensive data are available for these indexes for a large number of countries over many years. We therefore limit ourselves to a comparison of these three indexes in this paper. The nature of these indexes is briefly discussed below.

2.1 Genuine Savings

The World Bank (1997) proposed the original genuine savings rate (see, also Atkinson et al. 1997). It has been modified in subsequent years (now re-named adjusted net saving) and is currently calculated as:

$$\mathrm{GS} = \frac{\mathrm{GDS} - D_{\mathrm{p}} + \mathrm{EDU} - \sum R_{n,i} - \mathrm{CO_2Damage} - \mathrm{PM10\ Damage}}{\mathrm{GNI}}$$

where GS is genuine savings rate, GDS is gross domestic savings, D_{p} is depreciation of physical capital, EDU is current expenditure on education, $R_{n,i}$ is the rent from depletion of i-th natural capital (energy, mineral, and forest depletion are included), CO_2 damage is damage from carbon dioxide emissions (currently estimated as US$20 per ton of carbon times the number of tons of carbon emitted), and GNI is gross national income at market prices. PM10 damage is based on the estimate of particulate matter less than 10 μm in diameter for all cities with a population of 100,000 or more and is measured using willingness-to-pay to avoid mortality due to particulate emissions (World Bank 2007). GS is based on 'weak sustainability,' which assumes perfect substitutability between physical, natural, and human capital. A negative GS value implies that welfare is expected to decline in the future. GS has ranked Fiji at the top of the chart with a genuine saving rate of 38.6 followed by Namibia (34.1), China (31.8), and others. USA also is considered to be on a sustainable path with a genuine saving rate of 3.0. Thirty-three countries, including several developing countries, are noted to be on an unsustainable development path. The poorest performers are Chad at the bottom with a genuine savings rate of −58.4, followed by Uzbekistan (−47.9) and Republic of Congo (−47.4).

2.2 The Ecological Footprint

Proponents of 'strong sustainability' argue that natural capital should be considered separately from manufactured capital, because at critical stages overuse of ecological assets cannot be compensated for by economic assets. In line with this thought, Ecological Footprint analysis looks at whether nations are living within or beyond their biological capacity. The Ecological Footprint is a measure given in global hectares (that is, hectares of 'biologically productive space with world-average productivity') that "measures how much land and water area a human population requires to produce the resources it consumes and to absorb its wastes under prevailing technology" (Wackernagel and Rees 1996). Ecological budget can be stated as:

$$EB = \sum\nolimits_i BC - \sum\nolimits_i FP$$

EB is in balance when $\sum$BC (total biological capacity) = $\sum$FP (total footprint) (that is, EB = 0). If $\sum$FP exceeds $\sum$BC, then the nation is running an ecological deficit; if $\sum$BC exceeds $\sum$FP, the nation has an ecological reserve (WWF et al. 2006; Wackernagel and Rees 1996; Azqueta and Sotelsek 2007). Six categories are taken into account: cropland, pasture, forests, fisheries, built space, and energy. The footprint varies in proportion to population size, consumption per capita, and resource intensity of prevailing technologies. The Living Planet Report 2006 allocates about 1.8 global hectares (gha) per person to ensure sustainable consumption, given the Earth's productive land and sea space as well as available technologies. Ecological Footprint calculations form the basis for declaring October 6, 2007 as Ecological Debt Day, suggested to reflect that by that date humanity has consumed all resources provided by the Earth in 2007. In other words, ecological overshoot is 30%: it takes 1 year and 3 months for the Earth to generate what humanity is using in 1 year. (see, also Azar and Holmberg 1995; Den Elzen et al. 2005; Srinivasan et al. 2008). The ecological budget is highest in case of Gabon (17.8 gha) followed by Bolivia (13.7 gha), New Zealand (9.0 gha), and others. The bottom level performers are UAE (−11.0 gha), Kuwait (−7.0 gha), USA (−4.8 gha), and others (see WWF et al. 2006).

2.3 The Environmental Sustainability Index (ESI)

The Environmental Sustainability Index (ESI) was developed by the Yale Centre for Environmental Law and Policy (Bisbort 2003; YCELP et al. 2005). It uses 76 data sets (e.g., natural resource endowments, pollution levels, environmental management efforts, etc.) integrated into 21 indicators (I), with each indicator given an equal weight (w).

$$\mathrm{ESI} = \sum_{i=1}^{21} wI_i$$

These 21 indicators fall into five broad categories: (i) environmental systems, (ii) reducing environmental stresses, (iii) reducing human vulnerability to environmental stresses, (iv) societal and institutional capacity to respond to environmental challenges, and (v) global stewardship. A higher score implies that a country is relatively better positioned to maintain favorable environmental conditions for the future. Finland ranked at the top with a score of 75.1 followed by Norway (73.4), Uruguay (71.8), Sweden (71.7), and others. North Korea is placed at the bottom with an ESI score of 29.2, with Taiwan (32.7), Turkmenistan (33.1) as second and third poorest performers. While a negative value for GS or ecological balance implies unsustainable development, it is difficult to specify a threshold level for the ESI such that any ESI score above it can be considered a sustainable path. Though theoretically the ESI score can take values between 0 (most unsustainable) and 100 (completely sustainable), the actual estimates vary between 29.2 and 75.1. YCELP et al. have also classified these estimates in 5 quintile ranges of ESI scores (29.2–40.0, 40.5–46.2, 46.6–52.4, 52.5–59.6, and 59.7–75.1). For this paper, we have arbitrarily chosen an ESI score in bottom two quintiles (that is, an ESI score of 46.2 or less) as a reflection of unsustainable development.[1]

3 Empirical comparison of indexes

Here we compare the three indexes. The frequency distributions of the values of the indexes for the various countries are shown in Fig. 1a–c. The distributions of the values of the indexes by income classification are given in Fig. 2a–c. The results reflect a wide variation and disagreement among the indexes in ranking nations as ‘sustainable.’ Table 1 gives the Kendall tau-b rank correlation coefficients between the indexes, as well as with purchasing power parity GDP per capita (Y) and the HDI.[2] It can be seen that EF is negatively correlated with Y, the HDI and GS and positively correlated with ESI, while GS and ESI exhibit positive correlation with each other and with Y and the HDI.[3] The negative and positive (but low) correlation coefficients indicate that the various indexes point in different directions when addressing sustainability. This is disturbing and suggests that there is still little agreement on what constitutes a good aggregate environmental index and on how to rank nations as ‘sustainable nations.’ The disagreement is not necessarily surprising as the estimation methods are different in approach and can moreover be criticized on methodological grounds based on aggregation, arbitrary choices, and weighting

[1] The Yale Centre for Environmental Law and Policy (YCELP) has also developed an index known as Environmental Performance Index (EPI) which is suggested to supplement ESI. While ESI is a measure of a country’s long-term environmental trajectory, the EPI focuses on a country’s present environmental performance (see YCELP et al. (2008)). The focus of EPI is thus narrower. As the aim of our paper is to examine indexes of ‘sustainability’ we consider only comprehensive ones like EF, GS, and ESI, and do not include EPI.

[2] Kendall tau_b is a non-parametric correlation coefficient which delivers a more accurate generalization than Spearman’s coefficient of correlation when the data set contain many tied ranks.

[3] Data are collected from a variety of sources: GS from the World Bank (2007); EF from the Living Planet Report (WWF et al. 2006); ESI from YCELP et al. (2005); and HDI from the Human Development Report 2006 (UNDP 2006).

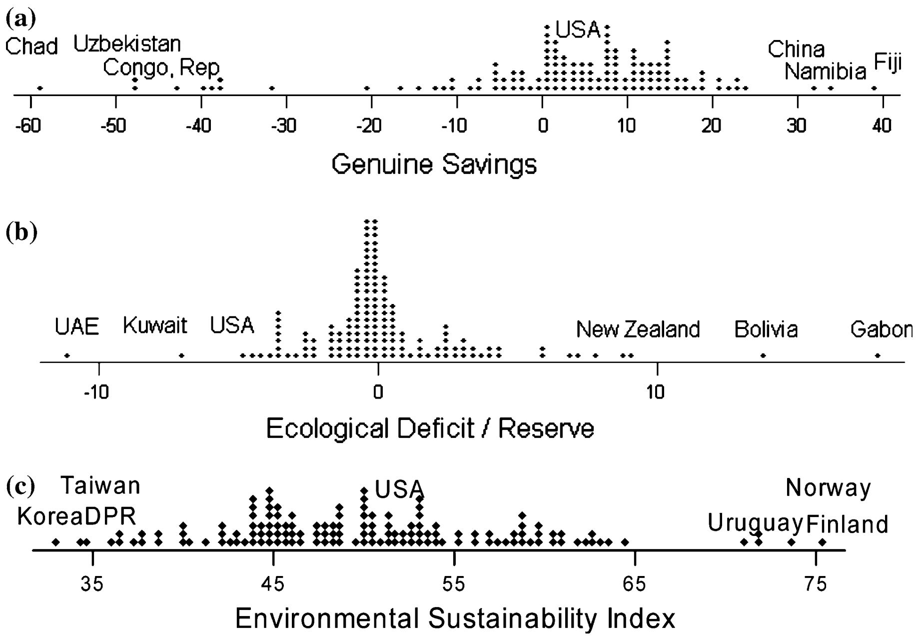

Fig. 1 Frequency distributions of the index values. **a** Genuine Savings, **b** Ecological Footprint, **c** Environmental Sustainability Index (*Sources*: **a** World Bank (2007); **b** WWF et al. (2006); **c** YCELP et al. (2005))

(Pillarisetti 2005; Ebert and Welsch 2004; van den Bergh and Verbruggen 1999; Gasparatos et al. 2007; Grazi et al. 2007).

We examined how many countries in different income and HDI groups are considered unsustainable by each index independently, by a combination of two indexes, and by all three indexes. Tables 2 and 3 provide information on the number of countries on an unsustainable path by income and HDI classifications of countries.[4] The results further emphasize the lack of agreement among the indexes for a large number of countries. While GS and ESI view many HICs and high HD countries on a sustainable path, EF suggests the opposite.

Figure 3 shows the shares of world output and world population that fall in unsustainable nations according to each of the indexes and their combinations. Using EF one arrives at a total population of 5.1 billion (82% of world population) and 85% of world GDP in unsustainable nations. Using ESI one finds that 3.9 billion people (64% of world population) and 34% of world GDP fall in unsustainable nations. With GS one obtains only 0.8 billion people (13.3% of world population) and 6.3% of world GDP in unsustainable nations, mainly developing ones. Combinations of indexes give slightly different shares. Generally, conclusions at this aggregate level are very sensitive to the type of index, with

[4] Economies are divided into income groups according to gross national income (GNI) per capita, calculated using the World Bank Atlas method. The groups are: low income countries (LICs), $765 or less; lower middle income countries (LMICs), $766–3,035; upper middle income countries (UMICs), $3,036–9385; and high income countries (HICs), $9,386 or more (World Bank 2005). The Human Development Report 2005 (UNDP 2005) classifies countries into three clusters: high human development (HDI is 0.8 or above), medium human development (HDI is 0.5 to 0.799), and low human development (HDI is less than 05).

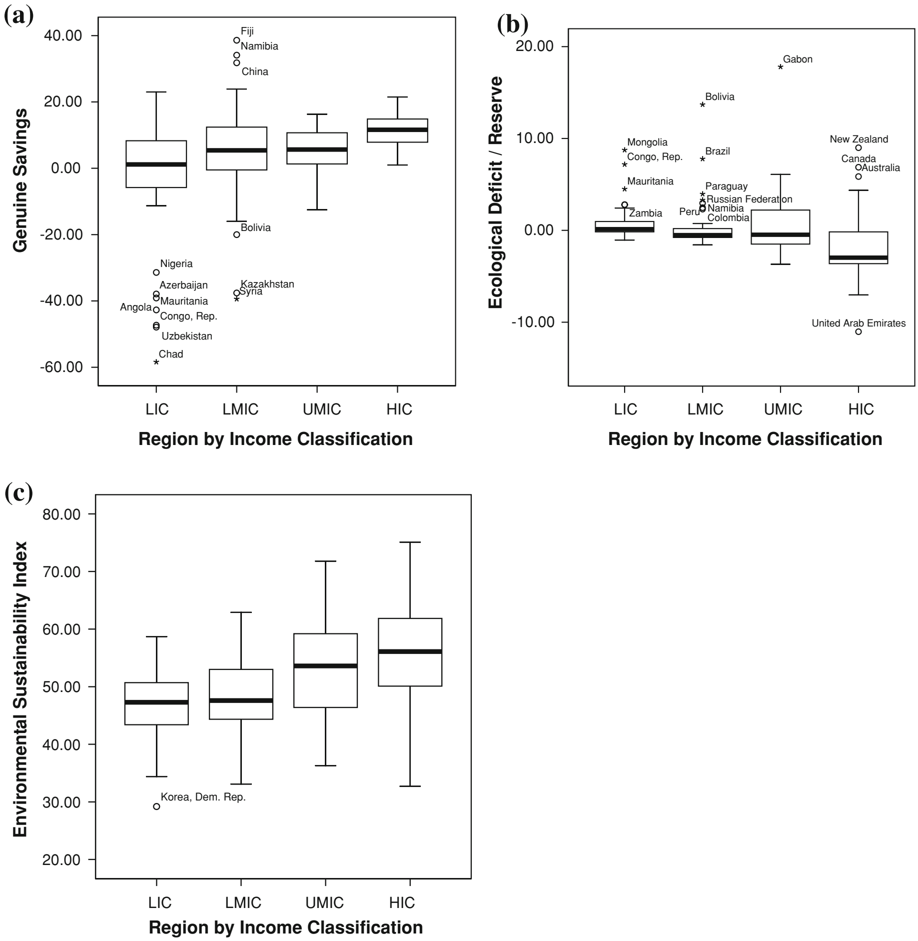

Fig. 2 Distributions of the index values by income classification. **a** Genuine Savings by income classification, **b** Ecological Deficit/Reserve by income classification, **c** ESI scores by income classification

EF offering the most pessimistic, ESI an intermediate, and GS the most optimistic perspective.

Table 4a provides the list of top 20 performers for each of the indexes and by all three indexes together (that is, the list of countries reflecting positive and high values of GS, EF, and a high value of ESI). Table 4b gives the bottom 20 performers for each index. Here it can be seen that 11 countries are considered unsustainable by all 3 indexes (that is, running an ecological deficit, a negative GS value, and an ESI score of 42.6 or less).[5] While EF positively projects developing countries which generally have relatively small ecological

[5] These 11 countries are out of a subset of 119 countries for which values of all three indexes are available. Countries included in the study are those for which at least one of the index values is available (the most recent values of the indexes are used: GS is available for 128 countries, EF for 147 countries and ESI for 146 countries). Thus the number of unsustainable nations by all three indexes can be much higher than 11, if data on all three indexes are available for more than 119 nations.

Table 1 Non-parametric correlations (Kendall tau_b)

		GS	EF	ESI	Y	HDI
GS	Correlation coefficient	1.000	−.139*	.178**	.249**	.240**
	Sig. (2-tailed)	–	.023	.004	.000	.000
	N	128	122	121	125	125
EF	Correlation coefficient	−.139*	1.000	.227**	−.277**	−.286**
	Sig. (2-tailed)	.023	–	.000	.000	.000
	N	122	147	141	135	135
ESI	Correlation coefficient	.178**	.227**	1.000	.285**	.304**
	Sig. (2-tailed)	.004	.000	–	.000	.000
	N	121	141	146	136	136
Y	Correlation coefficient	.249**	−.277**	.285**	1.000	.800**
	Sig. (2-tailed)	.000	.000	.000	–	.000
	N	125	135	136	168	168
HDI	Correlation coefficient	.240**	−.286**	.304**	.800**	1.000
	Sig. (2-tailed)	.000	.000	.000	.000	–
	N	125	135	136	168	168

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Table 2 Number of countries on unsustainable trajectories: nations classified by income

Index	Low income countries	Lower middle income countries	Upper middle income countries	High income countries	Total
All indexes	6	4	1	0	11
EF & ESI	17	15	6	4	42
ESI & GS	12	4	1	0	17
GS & EF	8	5	1	0	14
GS only	21	10	3	0	34
EF only	26	29	14	20	89
ESI only	27	16	6	5	54

footprints and considers many advanced countries as 'unsustainable nations,' GS and ESI by and large rank advanced countries favorably and view many poor countries as 'unsustainable nations.' While ESI considers five HICs (Belgium, Korea Republic, Kuwait, Taiwan, and UAE) as unsustainable, GS regards none of the HICs as being on an unsustainable path. Overall, 29 countries (12 LICs, 6 LMICs, 5 UMICs and 6 HICs) are viewed as progressing in a sustainable way by all the three indexes. These include all the 20 countries in column 1 of Table 4a as well as Benin, Cambodia, Côte d'Ivoire, Guinea-Bissau, Madagascar, Mali, Nicaragua, Panama, and Tanzania. These 29 countries together have 567 million people, thus covering only approximately 9% of the world population. Except for Brazil (with a population of 184 million), the remaining countries are small and medium sized countries (population wise) with population sizes between 1.5–45 million.

Taking a brief critical look at the index construction methodology reveals serious limitations of these indexes. GS is based on perfect substitution of all forms of capital

Table 3 Number of countries on unsustainable trajectories: nations classified by HDI

Index	Low HDI countries	Middle HDI countries	High HDI countries	Total
All indexes	2	9	0	11
EF & ESI	8	27	7	42
ESI & GS	7	10	0	17
GS & EF	3	11	0	14
GS only	11	22	1	34
EF only	13	44	32	89
ESI only	17	29	8	54

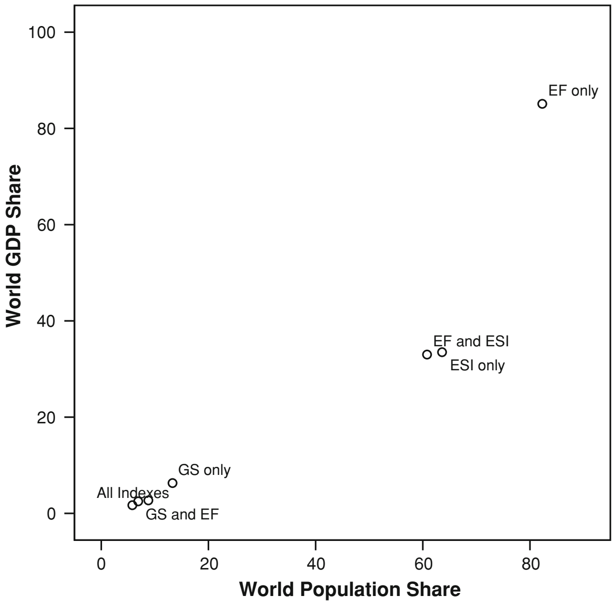

Fig. 3 Unsustainable shares of world output and population per index

which can yield seriously misleading implications and policies. For instance, if Brazil destroys all Amazonian forests and invests the sale proceeds as education expenditure, GS will stay the same or might increase. By extension, if all countries were to destroy all their forests and invest the proceeds as education expenses, this will have no impact as GS stays the same or increases. Thus relying on GS for policy can result in an "irreversible loss of 'critical natural capital'" (Muradian and Martinez-Alier 2001). Thus combining the different forms of capital and assuming perfect substitution can yield trivial and counter intuitive results (Pillarisetti 2005; Gowdy and McDaniel 1999). A related problem is that, for one country, it may perhaps work but not for the whole world. ESI seems more comprehensive but is arbitrary in terms of composition as it does not have a sound theoretical base. For instance, an environmentally important indicator 'eco-efficiency' receives the same weight as 'basic human sustenance,' 'participation in international collaborative efforts' and other social and economic indicators. Trade off between social and environmental goals implicitly assumes unlimited substitution which lacks a

Table 4 State of sustainability of nations

All indexes	GS only	EF only	ESI only
(a) Top performers by indexes			
Argentina	Fiji	Gabon	Finland
Australia	Namibia	Bolivia	Norway
Brazil	China	New Zealand	Uruguay
Canada	Morocco	Mongolia	Sweden
Central African Rep.	Nepal	Brazil	Iceland
Colombia	Honduras	Congo, Rep.	Canada
Finland	Korea, Rep.	Canada	Switzerland
Georgia	Ireland	Uruguay	Guyana
Ghana	Philippines	Australia	Argentina
Honduras	Lesotho	Mauritania	Austria
Latvia	India	Finland	Brazil
Malaysia	Sweden	Latvia	Gabon
Mongolia	Thailand	Paraguay	Australia
Namibia	Bangladesh	Argentina	New Zealand
New Zealand	Mongolia	Sweden	Latvia
Norway	Costa Rica	Namibia	Peru
Paraguay	Slovenia	Chile	Paraguay
Peru	Armenia	Peru	Costa Rica
Sweden	Austria	Botswana	Bolivia
Uruguay	New Zealand	Zambia	Croatia
(b) Bottom performers by indexes			
Algeria	Guinea	Libya	Vietnam
Azerbaijan	Venezuela	Portugal	Zimbabwe
Burundi	Lao PDR	Lebanon	Lebanon
Egypt	Zimbabwe	France	Burundi
Iran	Sudan	Trinidad and Tobago	Pakistan
Lebanon	Russian Federation	Germany	Iran
Nigeria	Malawi	Italy	China
Syria	Lebanon	Korea, Rep.	Tajikistan
Tajikistan	Ecuador	Greece	Ethiopia
Uzbekistan	Iran	Switzerland	Saudi Arabia
Zimbabwe	Bolivia	Netherlands	Yemen
	Nigeria	Japan	Kuwait
	Kazakhstan	Spain	Trinidad and Tobago
	Azerbaijan	Saudi Arabia	Sudan
	Angola	United Kingdom	Haiti
	Syria	Israel	Uzbekistan
	Mauritania	Belgium	Iraq
	Congo, Rep.	United States	Turkmenistan
	Uzbekistan	Kuwait	Taiwan
	Chad	United Arab Emirates	Korea, Dem. Rep.

theoretical basis. This makes ESI as much a social indicator as an environmental one. Thus Bhutan, which maintains a pristine environment, is highly eco-efficient and consumes extremely low amounts of global commons (negligible CO_2 and other pollutant emissions)still obtains almost the same ESI score (53.5) as the USA (53.0) which, with only 5% of the world population, consumes extremely large amounts of global commons by producing nearly a quarter of world CO_2 emissions and significant amounts of other pollutants that cause adverse climate change effects (e.g., Gore 2007; Sachs 2005; World Resources Institute et al. (2000); Centre for Health and the Global Environment 2005; Stiglitz 2006).

Both GS and ESI reflect bias toward advanced economies and seriously fail to adequately account for consumption of global commons and accumulation of ecological debt (Simms 2005). EF on the other hand, considers depletion of natural resources as the central element of sustainability and states that from a global perspective, humanity's consumption has exceeded the Earth's carrying capacity by 30%. EF thus suggest that scale of economic activity is perhaps most crucial of all sustainability issues and argues that, unless lifestyles are seriously changed and consumption of global commons brought down to sustainable levels, humanity at a global level will remain consuming at unsustainable levels (see also Daly (1996)). However, at the country level the estimates can yield misleading results as profligate countries may still show an ecological surplus thanks to a well endowed resource base (e.g., Australia) while prudent countries may still reflect ecological deficit because of a poor resource base (e.g., Moldova) (see also Lenzen et al. (2006)). The ecological deficit/surplus indicator reflects a close to autarkical normative perspective: each country should stay within its ecological capacity defined by its political boundaries. But the latter are arbitrary from an environmental angle, and deny the reasons of international trade and concentration of activities in space (agglomeration effects). The case of China is strange and disturbing as GS ranks China at the top 3rd of the list. But EF considers China as one of the few developing countries running ecological deficit and ESI places China as one of the poor performers. Similarly, Bolivia which is ranked as a top performer (2nd by EF and 19th by ESI) is registered as a bottom performer by GS (10th from the bottom). The largest economy in the world, the USA, is identified as a sustainable nation by GS and ESI, while EF places USA as one of the three worst performers (see, also United Nations Environment Programme (UNEP) et al. 2002).

The questions of sustainability of humanity's consumption and identifying sustainable nations cannot be conclusively answered using the three considered indexes. All indexes reflect methodological and measurement problems, and using each of them to rank sustainable nations or commenting on humanity's consumption may yield erroneous results. Despite the limitations and lack of agreement among the various indexes, it might be worthwhile to check which nations are ranked low according to all indexes, according to EF and ESI, or EF and GS, or ESI and GS. Besides the above 11 nations identified as the bottom performers by all indexes, EF and ESI also jointly identify 42 nations as unsustainable; EF and GS jointly consider 14 countries as unsustainable; and ESI and GS jointly view 17 countries as unsustainable. These nations perhaps most urgently would need to critically examine their economic development and environment policies.

4 Concluding remarks

Three aggregate indexes to analyze human consumption yield conflicting results. All indexes suffer from methodological limitations: GS can yield erroneous and counterintuitive results: by assuming infinite substitution across all forms of capital it neglects the loss of critical natural capital. GS and ESI seem to reflect a bias toward the level of income of a country. While GS considers all high income countries as sustainable, ESI views all but five high income countries as sustainable. Neither GS nor ESI can answer whether humanity's consumption is sustainable and within the limits of the ecological capacity. EF on the surface seems to suggest that humanity's consumption is overshooting and beyond the earth's regenerating capacity, but the methodological problems associated with EF can make the estimate unreliable. In particular, the notion that an ecological footprint should remain within the ecological capacity as defined by arbitrary national (political) borders reflects an implicit anti-trade bias. It denies the usefulness (economic and environmental) of international trade, including the capacity of trade to spatially distribute the environmental burden among the least sensitive natural systems. More generally, the EF lacks a good foundation for distinguishing between sustainable and unsustainable trade. This would require a more careful environmental evaluation of the production sources (including transport) of imports and exports.

If one believes that combinations of these indexes are more reliable than single index, a disturbing finding is that only 29 countries in the world economy—representing a fraction of countries in the world economy—are viewed as sustainable by all three indexes jointly. This may be taken as a suggestion at least that the majority of the nations in the world need to re-examine the environment-development linkages and policies. Moreover, for many small and other vulnerable nations, the GS and ESI indexes do not capture the vulnerability of nations to human-induced climate change, whereas the EF does this in an arbitrary way, namely through forestation to capture or compensate for CO_2 emissions. This approach implies an implicit assumption about the relative importance of climate change among environmental problems, without any clear basis in natural or social sciences (i.e. human preferences). Finally, calculation of the shares of world output and world population that fall in unsustainable nations according to each of the indexes shows little consistency among the indexes, with EF offering the most pessimistic, ESI an intermediate, and GS the most optimistic perspective. As a general conclusion, the observed lack of consistency is bad news for organizations and countries in search of a reliable aggregate environmental index.

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